Information Technology Laboratory

Innovating Network Metrology

Advanced Network Technologies Division

Mission:

Provide the networking industry with the best in test and measurement technology.

Goals:

- To improve the quality of emerging networking specifications and standards.

- To improve the quality of networking products.

Core Technical Contributions:
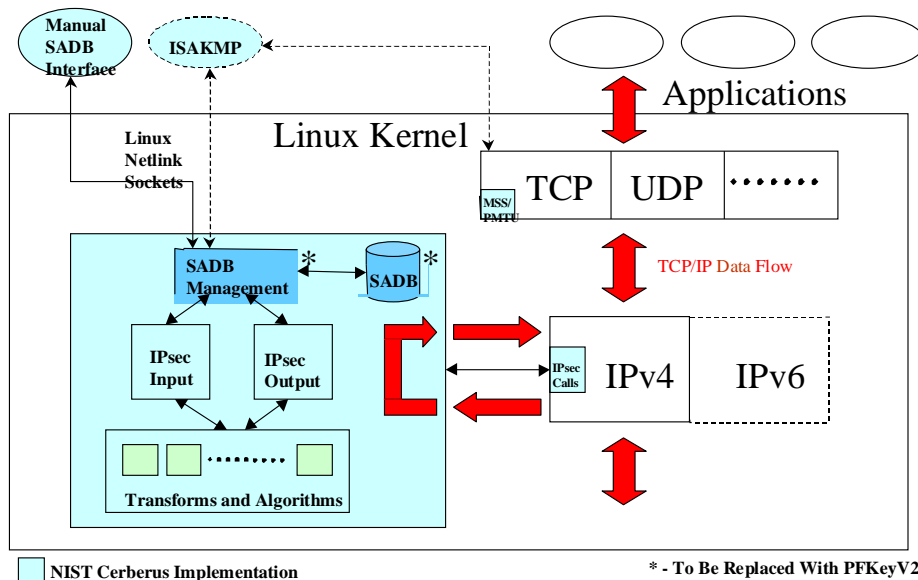
- Developing test and measurement tools, techniques, metrics, and data to assess conformance, interoperability, and performance

- Modeling and analysis from specifications to assess consistency, completeness, precision, and performance characteristics

- Prototyping and empirical studies from specifications to determine feasibility

A Concrete Example

- **High Speed Networking**

- **Internetworking**

- **Multimedia Networking**

- **Wireless Communications**

FOUR PRODUCTS

- IPSec Prototype (Cerberus)
- IPSec Interoperability Tester (WIT)
- Network Emulator (NIST Net)
- IP Integrated Services Performance Monitor (ISPI)

IP Security Prototype (Cerberus)

- Cerberus: 2nd Generation IPSEC in LINUX OS
- Public domain prototype with IPSEC, ISAKMP, ATM
- Platform for further IPSEC, IPv6 research
- Explore advanced application requirements: Digital Video

Selected Cerberus Users

Organization	Purpose
3COM	Testing
ANS	Testing
Ascend	Testing & Use
Bay Networks	Reference
BBN Technologies	Development Base
DEC	Reference
GSA	Testing and Demos
IBM	Reference
Intel	Reference
Ipsilon Networks	Reference & Testing
MCI	IPSec Evaluation
Microsoft	Reference
Oak Ridge NL	VPN Testing & Eval.
Sun Microsystems	Testing
TIS	Reference & Develop.

* - To Be Replaced With PFKeyV2

For more information: http://www.antd.nist.gov/antd/html/cerberus.html

IP Security Web-based Interoperability Tester (WIT)

- Practical testing tool - semi-automated, WWW driven tester
- Built around NIST Cerberus IPSec and Pluto++ IKE implementations
- WWW forms to navigate interoperability test scripts (~400)
- WWW / CGI driven configuration of Cerberus / Pluto++ prototype
- WWW-based / email examination of test results
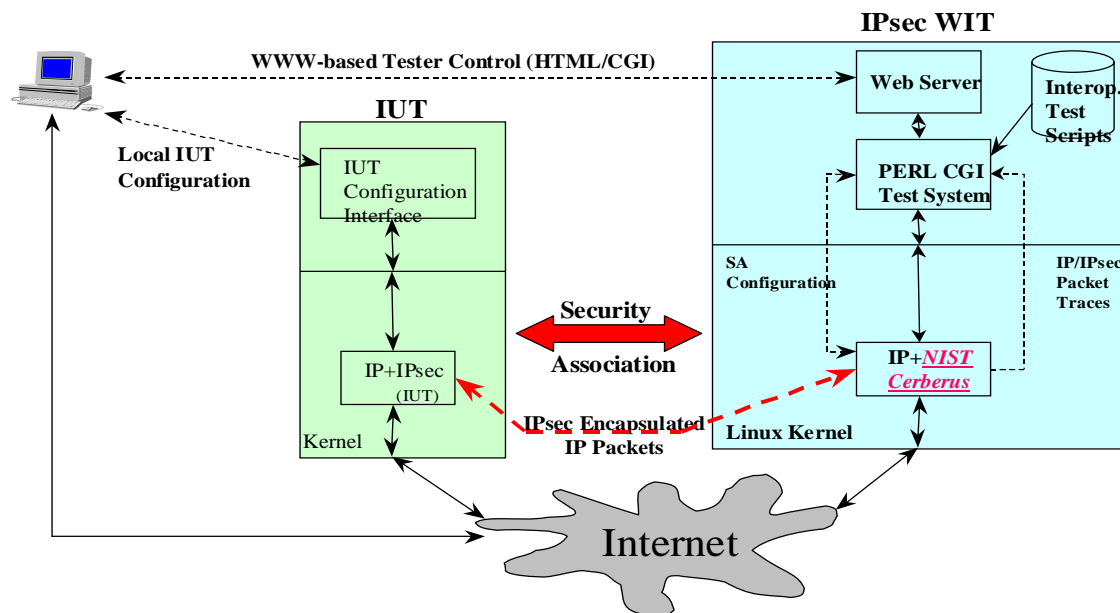
Selected WIT Users

Bay Networks
CISCO
IBM
IntraSecure Networks
Interlink
Milkyway
MIT
Naval Research Laboratory
Nokia
Office of Secretary of Defense
Phase2 Networks
RouterWare Inc.
Scarlet Fire
TeamWare Group
Wasantara Net
Xedia

IPsec WIT

WWW-based Tester Control (HTML/CGI)

IUT

Local IUT Configuration

IUT Configuration Interface

Web Server

Interop. Test Scripts

PERL CGI Test System

Security

Association

SA Configuration

IP/IPsec Packet Traces

IP+IPsec (IUT)

IP+*NIST Cerberus*

Kernel

IPsec Encapsulated IP Packets

Linux Kernel

Internet

For More Information: http://www.antd.nist.gov/antd/html/wit.html

NIST Network Emulator
(NIST Net)

- General purpose "cloud" performance emulator
- Linux Kernel loadable modules on Pentium base
- Allows for laboratory emulation of wide area network dynamics, including: bandwidth limitations; delay distributions; packet loss, congestion, and corruption; packet reordering
- Supports parameterization from trace files

Selected NIST Net Users

Organization	Purpose
3COM	Net. S/W Testing
AT&T	Simul. Net. Congest.
Bell Atlantic	Network Testing
Bay One Technologies	Testing Web Servers
Boeing	Net. Perf. Testing
Ericsson	Protocol Testing
GTE Labs.	S/W Development
IBM	Testing Net. S/W
Intel	Testing Net. Apps.
Mitre	Benchmarking Nets.
Motorola	Net. Research
NIMA	Test Collab. S/W
Nokia	Emulation
Renault	Net. QoS Simuation
SAP, A.G.	Testing Net. Apps.
Siemens	Test Net. S/W
U.S. West	SNMP Testing

For More Information: http://www.antd.nist.gov/antd/html/nist_net.html

Integrated Services Protocol Instrument (ISPI)

- Provides real time performance measurement of RTP streams
- Provides performance traces that can be fed into emulation tool.
- Allows for experimental interaction with resource reservation
- Supports a range of IP Integrated Services Protocols: RTP, RTCP RSVP, IP Multicast, SD, SDR

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┌─────────────────────────────────────────────────────────────┐
│ ▼        NIST Integrated Services Protocol Instrument (ISPI)  │
├─────────────────────────────────────────────────────────────┤
│ Jan 29, 1998            -*- I S P I -*-          NIST/ITL/ANTD│
│ 16:22:07      NIST Internetworking Technologies Group  Version 0.0│
│ ─────────────────────────────────────────────────────────── │
│              [ISPI MONITOR: Single Receiver]                 │
│       UserName: Michael Speer(Sun) <speer@eng.sun.com>       │
│                [Tool: vic-2.8/SunOS-5.6-sun4u]               │
│   Address: 224.2.172.238 Media: video  Payload: H261  Attr: -none-│
│        Port: 51482      TProt: RTP/AVP  Channel: 0    Rate: 65536│
│ ═══════════════════════════════════════════════════════════ │
│                      ___by_abs_second___  _Packets_  ___Total___│
│  SRC Sender Info     KBit Frame Pkt %PLost Lost Late KByte Packet│
│                                                              │
│  *> 129.6.55.33:32954  6.8  0.1   2  29.6   420    0  6.40K   997│
│  S> 129.6.55.33:32955 10.9  ---   1  ---    ---  ---  8.89K  1.41K│
│                      ___by_abs_second___                     │
│  SRC Receiver Info   KBit Frame Pkt %PLost  TotalPktLost  Jitter│
│                                                              │
│  R> Michael Speer(Sun) 12.0  --- ---  0.0        165        0│
│                                                              │
│            Type Resv   Avg   Peak Bucket MinPol Path  Band Slack│
│             of  Style  Rate  Rate  Depth  Unit  MTU  Width Term│
│ Reservation Info Serv r(Kbps) p(Kbps)  b(B)  m(B) M(B) R(Kbps) S(ms)│
│ ─────────────────────────────────────────────────────────── │
│ T> Sender Tspec        128.0 128.0  16000   576  9188        │
│ L> ISPI Rspec   cl  WF   5.0   5.0      5    50  1500        │
│ F> Receiver Rspec No resv status                             │
└─────────────────────────────────────────────────────────────┘
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Selected ISPI Users

Organization	Purpose
3COM	Product Testing
American TransInternet	Product R&D
Deutsche Telekom	Protocol Testing R&D
IBM	Router Testing
Intel	Net. Mgmt. R&D
Mitre	RSVP QoS R&D
Nexabit Networks	Router Testing
Northwestern U.	R&D for Internet II
Sony	Multimedia QoS R&D
Telephonica	RSVP QoS R&D
Torrent Networking	RSVP QoS R&D

For More Information: http://www.antd.nist.gov/antd/html/ispi.html

Information Technology Laboratory

Innovating Network Metrology

Division Resources

FY 1999 Staff Composition

Advanced Network Technologies Division

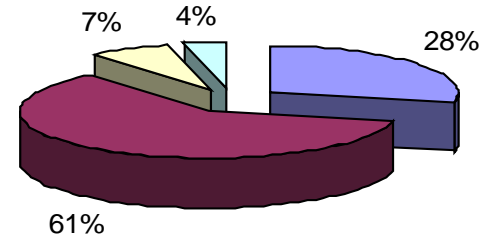**NIST** — *Innovating Network Metrology*

General Staff Composition

5

23

34
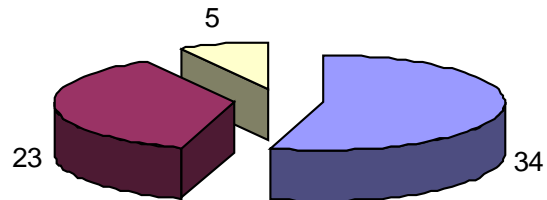
■ Staff Researchers ■ Guest Researchers □ Administrative Support

Research Staff Composition By Degree

7%   4%

28%

61%

■ PhD ■ MS □ BS □ Other

Research Staff Composition By Discipline

5%   7%

32%

56%
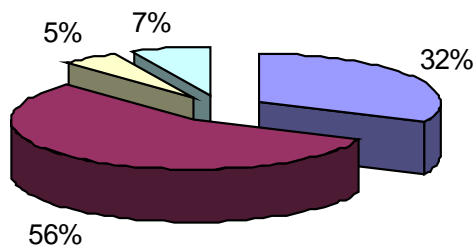
■ EE ■ CS □ Math □ Other

Research Staff Composition By Technical Area

18%   4%   26%

29%   23%
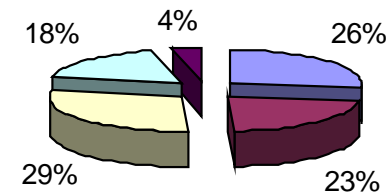
■ High Speed Nets ■ Internetworking □ Multimedia
□ Wireless   ■ Other

FY 1999 Funding Sources (estimated)

Advanced Network Technologies Division

Innovating Network Metrology

Labor and Other Expenses $7.3 M

$2.0 M

27%

$.4 M

5%

68%

$4.9 M
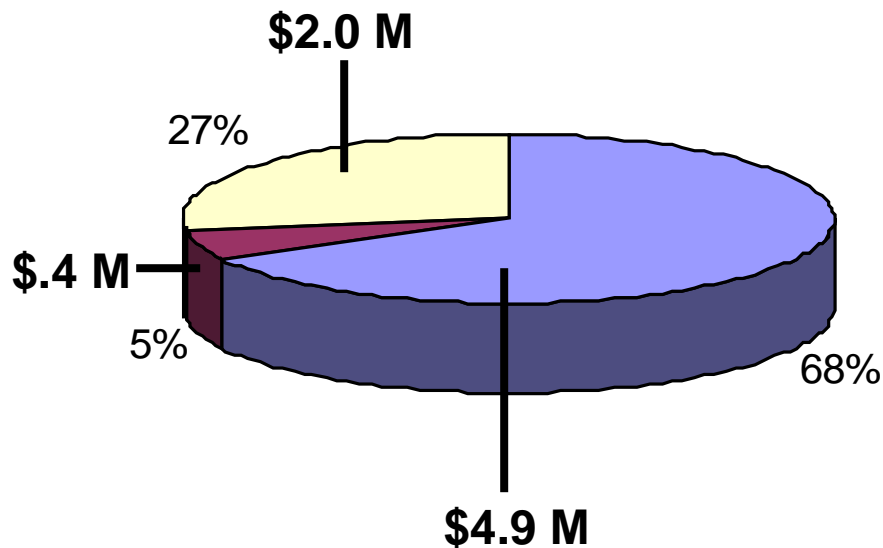
DARPA
NCS
NSA
GSA

- □ Internal ITL
- ■ Other NIST
- □ External Government

MEL
ATP

**$.2 M Capital Equipment Budget
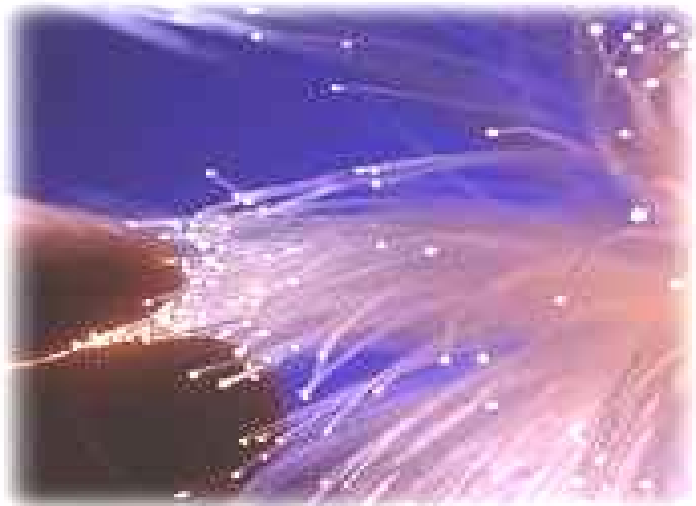(not included in pie chart)**

A Technical Overview

Current Technology Emphases

- **High Speed Networking**

- **Internetworking**

- **Multimedia Networking**

- **Wireless Communications**

High Speed Networking

Objectives

To improve commercial standards that underlie high speed backbone and access networks.

To develop tests, tools, and techniques that ensure conformance to standards and that enable interoperability among high speed networking elements.

To research and develop improved protocols for accessing high speed backbone networks.

Recent and Planned Products

Conformance tests for Digital Storage Media Command and Control (DSMCC), which is now part of the MPEG2 standard.

An ATM **simulator** used to study traffic management.

Formal models and **conformance tests** for ATM PNNI protocols.

Technical papers on Hybrid Fiber Coax protocols and design and on traffic management.

A WDM network **simulator** (new proposal).

Collaborators/Customers

- Industry Collaborators: **Bell Labs**
- Federal Partners: **DARPA, NCS**
- Standards Groups**: ATM Forum**, **IEEE 802.14, ISO, ANSI T1, SMPTE**
- Customers: **100's of companies, universities, and federal labs** downloaded our ATM simulator this year

Internetworking

IETF

namt

Reference Implementations Test Tools

Application Benchmarks, NGI Testbed

Pulic Standards for NGI Technologies

NGI Network Technology NGI Applications

INFORMATION TECHNOLOGY LABORATORY — Internetworking Technologies Group

IP QoS, IPv6, Mobile IP, IPSec, Key Mgmt, PKIX, IPMcast, Voice/IP, IPM

Research Prototypes, Measurement Tools, Modeling & Analysis

NGI

Objectives

To research and develop new techniques and tools to test and evaluate next generation internetwork technology at all stages of its development and deployment.

To expedite standardization, commercialization and deployment of new internetworking technologies.

To deliver practical test and measurement technology to the Internet research and product development industry.

Recent Products

Reference prototype for the Internet Protocol Security (IPSEC) standards.

NIST Switch, a **research prototype** of MPLS QoS mechanisms.

An Internet network **emulator**.

A Web-based **interoperability tester** for security protocols.

Five **IETF** IP security **standards**.

Collaborators/Customers

- Standards Groups: **IETF**
- Federal Partners: **DARPA, NASA**
- NIST Collaborators: **MEL/NAMT**
- Customers: **100's of companies, universities, and federal labs** use our reference implementations and test tools.

Multimedia Networking

NIST

Innovating Network Metrology

IETF

MPEG

W3C

MPEG-1/2/4/7 media types

IETF standard protocols (rtp/rtsp/etc)

W3C content technologies

Research prototypes/ Measurement tools

http://www.antd.nist.gov/madvtg
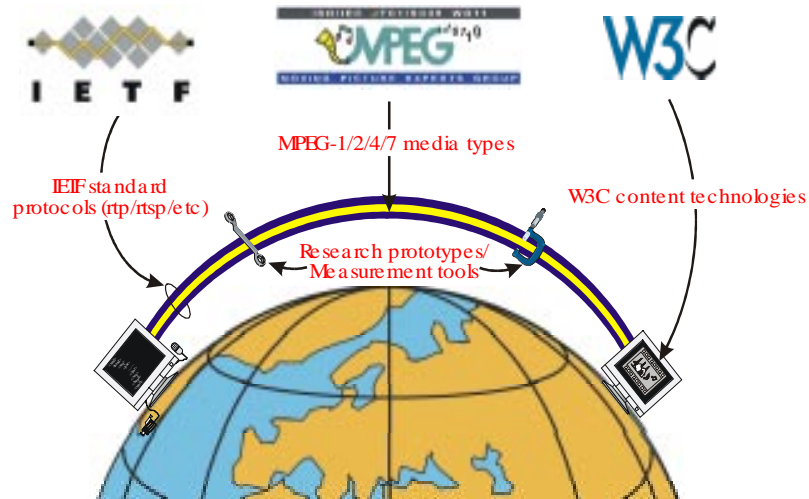
Collaborators/Customers

- Industrial Collaborators: **Compaq**
- Standards Groups**: W3C, MPEG, IETF, SMPTE**
- NIST Collaborators: **ATP, MEL/NAMT**

Goal
To facilitate the development of multimedia products

Objectives

Develop new image metrics

Develop and collect tools, prototypes, and tutorial material

Provide technical contributions to multimedia standards

Recent and Planned Products

A **reference implementation** video server**,** nistVoD, for MPEG-1/2 over RTP/RTCP/RTSP
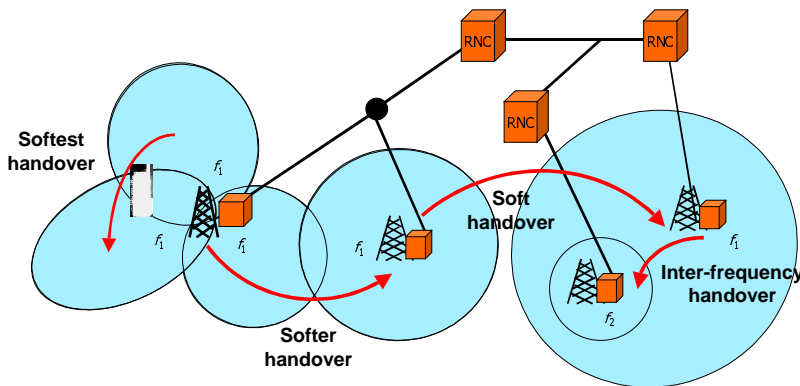
Hosted first **SMIL interoperability tests**.

MPEG-2 **video extraction tool**

Developed S2M2 Java Applet-based **SMIL player**

Co-authored W3C **SMIL 1.0 Recommendation**

Technical publications on image metrics and enhancement algorithms

Establishing 2D/3D BIFS **testing profiles for MPEG 4**

Wireless Communications

Softest handover

f_1

f_1

f_1

f_1

Soft handover

f_1

f_1

f_1

Inter-frequency handover

f_2

RNC

RNC

RNC

Softer handover

Objectives

To develop measurements and tests for emerging wireless technologies, including IMT-2000, LMDS, MANET, and Bluetooth.

To expedite convergence on national and international standards for wireless communications.

To design and develop improved fundamental techniques for transmitting multimedia data on wireless channels.

Collaborators/Customers

- Industrial Collaborators: **Ericsson, Nokia, Lucent, IBM, Qualcomm**
- Federal Partners: **NTIA**, **DARPA, FCC**
- NIST Collaborators**: ATP, EEEL**
- Standards Groups**: TIA, T1, ITU, IETF, IEEE, ETSI, Bluetooth SIG**

Planned Products

A **test workbench** for evaluating IMT-2000 technical specification.

A **reference implementation** of Bluetooth air interface specification.

An evaluation platform for MANET protocols.

Algorithms and **software** for coding/decoding and modulation of MPEG video for LMDS channels.

FY99 Technical Agenda

FY 1999 Technical Agenda

Ending Work

ATM Testing & Protocol Modeling
HFC Performance Assessment
NIUF Support
Digital Video Over ATM Testing
IPV6 Testing & Evaluation

Continuing Work

IP QoS Testing & Evaluation
IP SEC
SMIL Interoperability Testing
MPEG-2 Testing (moving to 4/7)

Starting Work

IMT-2000 Evaluation
LMDS Performance Assessment
Bluetooth Modeling & Assessment
MANET Performance Assessment
DWDM Network Metrology
WDM Simulation Toolkit

Under Consideration

Voice Over IP Test & Measurement
IP Performance Measurement
WDM QoS Research
MPEG 4 & 7 Test & Evaluation

Internetworking
Wireless
High Speed Nets
Multimedia

Our Current Watch List

Mobile Code

- **Active Nets -** for dynamic reconfiguration of test & measurement systems

- **Jini -** for plug-and-play network-based services

- **Java Chip & JavaOS -** for higher performance in mobile code execution in portable devices

Multicast

- **Scalable, Reliable Multicast (SRM) -** for Fault-Tolerant Group Communication

- **IP Multicast** - for location-independent communications among systems of mobile programs

Wireless

- **Earth Orbiting Satellite Systems (LEOS, MEOS, HEOS, & GEOS)** - for integrated voice and data and for internetworking with land-based systems

- **Gigabit Wireless -** for stationary and mobile users

Information Models

- **Multi-Layer, Multimedia IMs -** for matching information to bandwidth, computing, display, and task

- **Integrated Decoders -** for enabling devices to handle previously unseen formats

SUMMARY OF ENDING WORK

ATM Network Protocol Testing
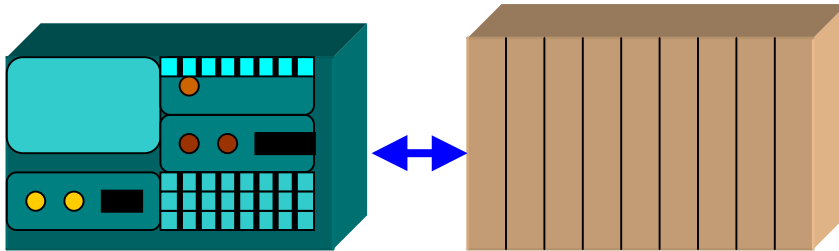
Goal

- To speed the deployment of standard conformant and interoperable ATM equipment for use in high speed networks.

Technical Objectives

- Develop Protocol Implementation Conformance Statements (PICS) and Abstract Test Suites (ATS) for the various ATM protocol specifications, recommendations, and standards.
- Develop Interoperability (IOP) Test suites to test the inter-operation of different manufacturers' equipment.
- Develop software tools for evaluating network routing performance and implementation of test suites.

Impact

- Use of the PICS allows testers to select tests to develop and execute and allows customers to determine an implementation's capabilities or features.
- Use of the ATSs and IOP and test tools permits test equipment manufacturers and test houses to quickly implement and market conformance and interoperability tests.
- Use of the software tool allows network designers and planners to test potential ATM networks without the high equipment costs.

Customers and Collaborators

Customers
- Test Equipment vendors, switch vendors and network operators
- Universities and research institutes
- Standards organizations: ANSI T1, ITU-T, and ATM Forum

Collaborators
- Test equipment vendors (GN Nettest, Hewlett-Packard, RADCOM, ADTECH)
- Equipment vendors and network operators (Hyundai, Fore, Bell Atlantic, Korea Telecom)
- Testbeds (UNH, MCNC, ATDNet)
- Research institutes (Electronics & Telecommunications Research Institute (ETRI))

Accomplishments (FY 94 - 99)

- Developed PICS for Service Specific Connection Oriented Protocol (SSCOP) (FY 94)
- Developed two Conformance ATS for ATM Layer (FY 95)
- Developed two PICS for ATM Layer (FY 95)
- Developed ATS for SSCOP (FY 96)
- Developed ATS for ATM Adaptation Layer type 5 (AAL5) (FY 96)
- Developed PICS for AAL type 2 (AAL2) (FY 97)
- Developed PICS for AAL2 SSCS for Trunking (ITU-T I.366.2) (FY 98)
- Developed two PICSs for the Signaling Layer (FY 97-99)
- Developed ATS for Private Network-Network Interface (PNNI) (FY 98)
- Developed Interoperability Tests for PNNI (FY 98)
- Designed and implemented a software tool for evaluating the performance of PNNI routing protocol. (FY 98)
- Developed ATS & tool for Available Bit Rate (ABR) service (FY 99)
- Developing ATS for the ATM Signaling Layer (FY 99)

ATM Network Protocol Modeling
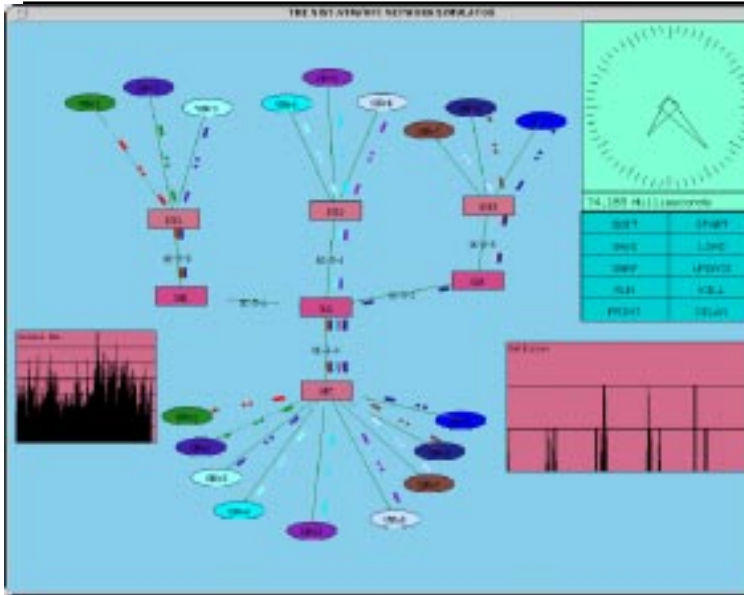
Goals

To expedite the standardization of ATM network protocols and evaluate their performance.

Technical Objectives

- Develop tools for ATM network planning and protocol performance evaluation.
- Conduct modeling and performance evaluation of ATM traffic management protocols and flow control mechanisms (Available Bit Rate service).
- Conduct modeling and performance evaluation of ATM routing protocol (PNNI).

Impact

- NIST ATM Network Simulator is widely used by industry, universities, other government agencies (50 request per week).
- Modeling and performance evaluation reports assisted ATM Forum to reach consensus.

Customers and Collaborators

Customers

ATM industry: vendors, service providers, users.
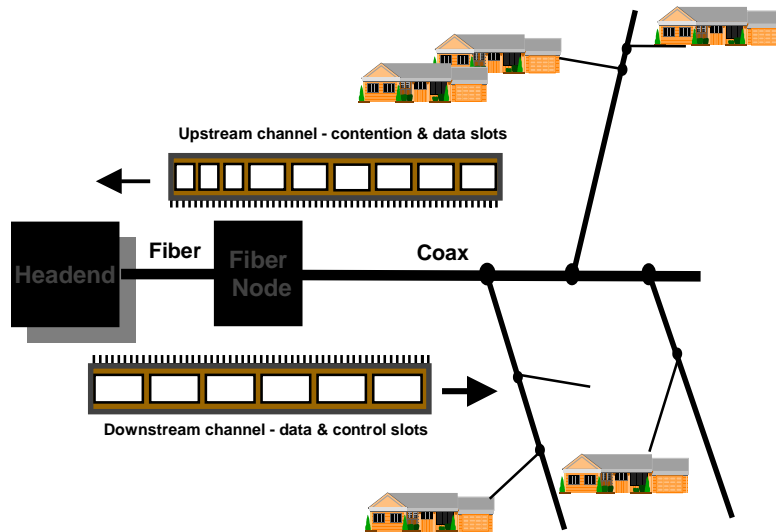Universities, Research Laboratories.
Government Agencies.

Collaborators

University of Virginia, Charlottesville.
Ecole Nationale Superieure de Telecommunication-
  Bretagne, France.
Hyuandai Network Systems

Accomplishments (FY 94 - 99)

- Completed first version of NIST ATM Network Simulator and submitted reports to ATM Forum on performance comparison of credit-based and rate-based flow control mechanisms.   (FY 94)
- Released V2 of the NIST ATM Simulator including ABR rate control mechanism.   (FY 95)
- Developed the first model of the PNNI protocol (FY 95)
- Conducted a study of ABR Service flow control switch mechanisms.   (FY 98)
- Developed a 2nd model of PNNI for automatic generation of conformance test suites.   (FY 98)
- Released V4 of the NIST ATM/HFC Simulator including HFC network module, traffic source modules (TCP Tahoe and Reno, MPEG2 GOP GBAR, self-similar), ATM control for TCP/IP, and ABR flow control.   (FY 99)
- Developed simulation tool for PNNI and conducted performance evaluation of PNNI implementations (FY99)

Modeling and Performance Evaluation of Hybrid Fiber-Coax Networks

Upstream channel - contention & data slots

Fiber

Headend

Fiber Node

Coax

Downstream channel - data & control slots

Goals

To conduct an unbiased evaluation and assist the IEEE 802.14 group in the standardization of MAC protocol for Hybrid Fiber/Coax networks.

Technical Objectives

- Model and evaluate MAC protocol proposals from IEEE802.14 members.
- Evaluate priority schemes to support Quality of Service.
- Study end-to-end performance issues: improving the effectiveness of ATM and TCP/IP traffic over HFC networks.

Impact

- Performance evaluation reports helped expedite standards for HFC networks (IEEE 802.14 WG, SCTE/ITU-T).
- Conference and journal papers informed the research community, cable system vendors and operators on the state-of-the-art in the area of MAC protocol modeling and implementation.

Customers and Collaborators

Customers

IEEE 802.14 WG, SCTE, Cable TV vendors and operators.

Collaborators

IBM, Zenith Electronics, Scientific Atlanta, LanCity, Com21, 3Com, Motorola, DEC.
University of Virginia, Charlottesville.

Accomplishments (FY 96 - 99)

- Developed evaluation process specification and produced MAC performance evaluation reports for IEEE802.14 group. Results were incorporated into draft standard.   (FY96-97)
- Enhanced the NIST ATM network simulator to include HFC network protocols, IEEE802.14 & SCTE.   (FY97-98)
- Produced papers on contention resolution algorithms, bandwidth allocation, and priority schemes: *4 conference papers, 3 journal articles*.   (FY97)
- Studied end-to-end performance issues for TCP/IP, ATM traffic control: *2 conference papers, 2 journal articles.*
(FY98)
- Continued research in comparison between IEEE 802.14 and SCTE MAC protocols, and in study of HFC QoS issues: *2 conference papers.*   (FY99)
- Completed PICS Proforma for Annex B of the IEEE 802.14 standard.   (FY99)

North American ISDN Users' Forum

Goals
- To provide users the opportunity to influence developing ISDN technology to reflect their needs;
- To identify ISDN applications, develop implementation requirements, and facilitate their timely, harmonized, and interoperable introduction; and
- To solicit user, product provider, and service provider participation in the process.

Technical Objectives
- Develop implementation agreements and define applications.
- Develop standard conformance tests.
- Develop guidelines for ISDN users and providers.

Impact
- NIUF has met its technical objectives and has provided an open industry forum in which users and equipment vendors can provide input into the evolving versions of ISDN deployed in North America.

Customers and Collaborators

Customers
- ISDN Stakeholders (ISDN Users, ISDN equipment manufacturers, ISDN Service Providers)
- Regional ISDN User Groups

Collaborators
- NIUF Cooperative Research and Development Agreement (CRADA) members and participants, including ADTRAN, Ameritech, AT&T Bell Laboratories, Bell Atlantic, Bellcore, Bell South, Defense Information Systems Agency, EICON, Ericsson, GTE, InteCom, Lucent Technologies, Network General, Northern Telecom, Siemens, TASC, U.S. Air Force, and U.S. West
- Liaisons with ANSI, ITU-T, ATM Forum, ISDN user forums in Europe and in Asia, and Multimedia Communications Forum

Accomplishments

- 14 Implementation Agreements have been completed, including
   - ISDN Wiring and Powering Guidelines - for Residential and Small Businesses and Campus environments,
   - ISDN Ordering Codes.
- 12 Conformance Tests completed; 3 internationally standardized in ITU-T.
- 153 active applications for development of Application Profiles have been accepted.
- Application Profiles have been completed for 13 applications.
- Catalog of ISDN Solutions developed.
- * Participation in the Transcontinental ISDN Project '92 (TRIP '92) earned the NIUF and Corporation for Open Systems International (COS) the InfoWorld Publisher's Industry Milestone Award for 1992 Product of the Year.

Digital Video Over ATM Testing
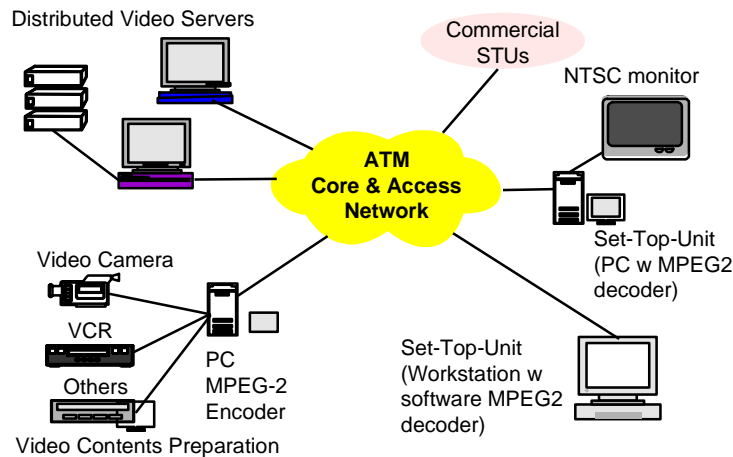
Goal

To foster interoperability of digital video products and services over ATM networks.

Technical Objectives

- Develop a reference implementation of DAVIC compliant Video-on-Demand (VoD) system (set-top units and video servers) for interoperability testing.
- Develop conformance and interoperability testing methodologies and test suites for testing of DAVIC compliant VoD systems.
- Study the QoS requirements for transport of digital video data over ATM Networks.
- Study the characteristics of variable bit rate MPEG2 compressed video sources.

Impact

- Use of test tools improves the interoperability of VoD products.
- Knowledge of QoS requirements and traffic patterns improves support of digital video over ATM networks.

Customers and Collaborators

Customers
- DAVIC members including equipment vendors, network operators, content providers and consumers
- Universities and research institutes.
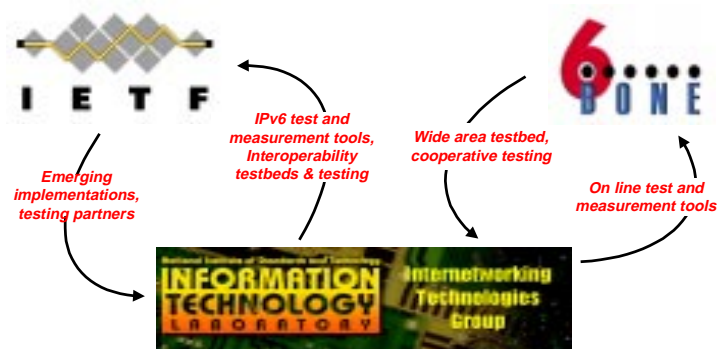- Standard organizations: ISO/IEC JTC1, SMPTE, and ANSI NCITS

Collaborators
- Columbia University
- Korean Telecomm, and Electronics & Telecommunications Research Institute, Korea.
- Bellcore, Bell Atlantic.
- Advanced Technology Program, NIST

Accomplishments

- Participated in a DAVIC interoperability test event at Columbia University with participants from 4 countries.   (FY 96)
- Completed a reference implementation of DAVIC VoD system which allows remote testing through Web access.   (FY 96-97)
- Completed the Conformance and Interoperability section of the DAVIC v1.2 Specifications.   (FY 97)
- Completed a test suite for MPEG2 part 6 (DSMCC) which was included in ISO/IEC MPEG2 standard part 10.   (FY 97-98)
- Developed a test tool for the above DSMCC test suite. (FY 98)
- Completed QoS testing of a VoD system with Bellcore over wide area ATM network between Gaithersburg, MD and Morristown, NJ   (FY 97-98)
- Developed a variable bit rate MPEG2 traffic source model (the GOP GBAR model) and incorporated it into the NIST ATM Simulator.   (FY98-99)

Next Generation Internet Protocols (IPv6)

IPv6 test and measurement tools, Interoperability testbeds & testing

Emerging implementations, testing partners

Wide area testbed, cooperative testing

On line test and measurement tools

Goal

To research and develop test and measurement tools for IPv6 and to facilitate early vendor interoperability testing and pilot deployment activities on the 6Bone.

Technical Objectives

- Establish IPv6 interoperability testbed & facilitate vendor testing.
- Facilitate the establishment of the 6Bone.
- Devise test and measurement tools for IPv6 and 6Bone network.

Expected Impact

- Deliver testing technology that makes a demonstrable impact on the IPv6 research and development community.

Potential Customers and Collaborators

Customers
- IETF IPv6 working groups
- 6Bone community.
- Dec, Sun MS, Bay Network, Telebit, Cisco.

Collaborators
- NRL
- Korea Telecom
- Dec, Sun MS, Bay Network, Telebit, Cisco

## Recent Products

- *NIST 6Bone Monitor* - 1st on line monitoring and measurement system for the 6bone   (FY97)
- *LibcapV6* - IPv6 extensions to Berkeley packet filter and extension to BPF based test tools (e.g. tcpdump)   (FY98)

Planned Accomplishments (FY99-00)

- Release *V6View* - IPv6 monitoring and analysis tool   (FY99)
- **Conclude IPv6 project**   (FY99**)**

SUMMARY OF CONTINUING WORK

IP Quality of Service
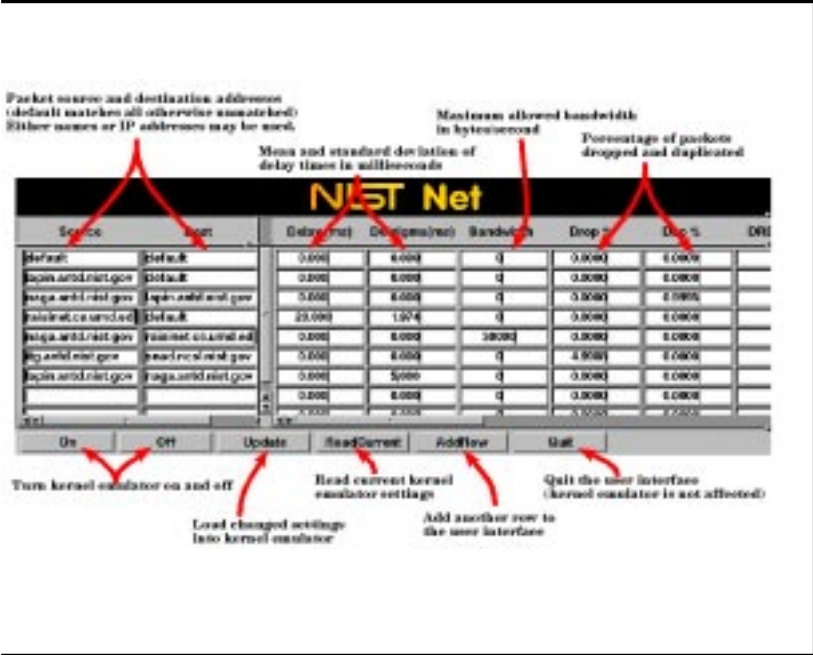
Goal

To research and develop testing methodologies and tools that will (1) enable the design and engineering of QoS sensitive applications over today's Internet technology; and, that will (2) expedite the design, standardization, and commercial implementation of new IP QoS technologies.

Technical Objectives

- Devise tools to assist the development of adaptive applications over today's Internet technology.
- Research and develop methodologies and tools to enable testing and experimentation with distributed multiparty QoS routing and signaling protocols.
- Evaluate algorithms and protocols for scalable QoS routing and signaling.

Impact

- Deliver testing technology that makes a demonstrable impact on the QoS research and development community.

Customers and Collaborators

Customers
- Our test tools and prototypes are being used by 100s of organizations in the Internet research and development community.

### Collaborators
- DARPA, NIMA, NASA AMES / NREN
- ETRI
- Darmstadt University, Chungnam National University

Recent Products

- *NIST Net* - tool for emulating Internet performance dynamics (FY98)
- *ISPI* - measurement and experimentation tools for RSVP   (FY98)

Planned Accomplishments (FY99-00)

- Release *DIPPER* - Distributed test tool for QoS signaling   (FY99)
- Develop *NISTSwitch* - MPLS/QoS routing prototype   (FY99)
- Research and development scalable MPLS based QoS routing algorithms   (FY00)
- Develop large scale simulation capability for traffic engineering and QoS scaling analysis of MPLS protocols   (FY00)

Internet Security Protocols
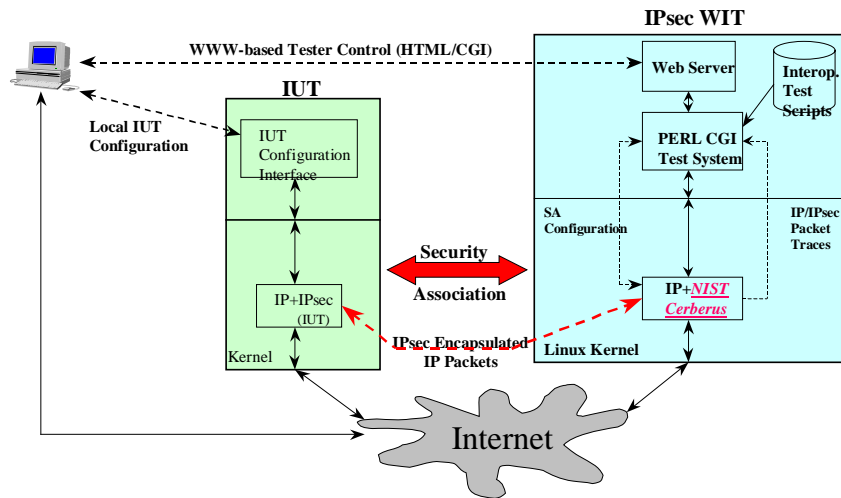
Goal

To expedite the research, development, standardization and commercialization of next generation Internet security and IPv6 technology. To deliver rapid prototypes and testing technology that makes a demonstrable impact in the IPsec research and development community.

Technical Objectives

- Expedite the development and improve quality of IETF IPsec standards
- Develop leading edge prototypes of emerging IETF IPsec specifications.
- Design and develop automated testing technology that will expedite the commercial availability of IPsec products.
- Research protocols and techniques for security policy management and advanced testing and verification techniques.

Expected Impact

- Deliver testing technology that makes a demonstrable impact on the Internet security research and development community.

Potential Customers and Collaborators

Customers
- IETF IPsec working groups
- Our test tools and prototypes are being used by 100s of organizations in the Internet research and development community.
- ANX security working group.

Collaborators
- NSA
- INRIA, Korea Telecom
- Cisco, Bay Networks, IBM T.J. Watson, BBN Technologies, NSA, Sable Systems

Recent Products

- *Cerberus/PlutoPlus* - reference prototype of IETF IPsec and IKE protocols   (FY98)
- *IPsec-WIT* - on line, WWW based interoperability test system for IPsec / IKE.   (FY98)

Planned Accomplishments (FY99-00)

- Expand test systems to address PKIX certificate protocols   (FY99)
- Analyze the applicability of IPsec to IPv6   (FY99)
- Prototype and analyze security policy management protocols (FY00)
- Develop formal modeling techniques to assess the security properties and generate test suites for IPsec / IKE / PKIX   (FY00)
- Analyze the scalability of IPsec / IKE / PKIX in large scale VPN environments   (FY00)

SMIL Interoperability Testing

S2M2 SMIL Player
(Java Applet-based)

Objectives

.
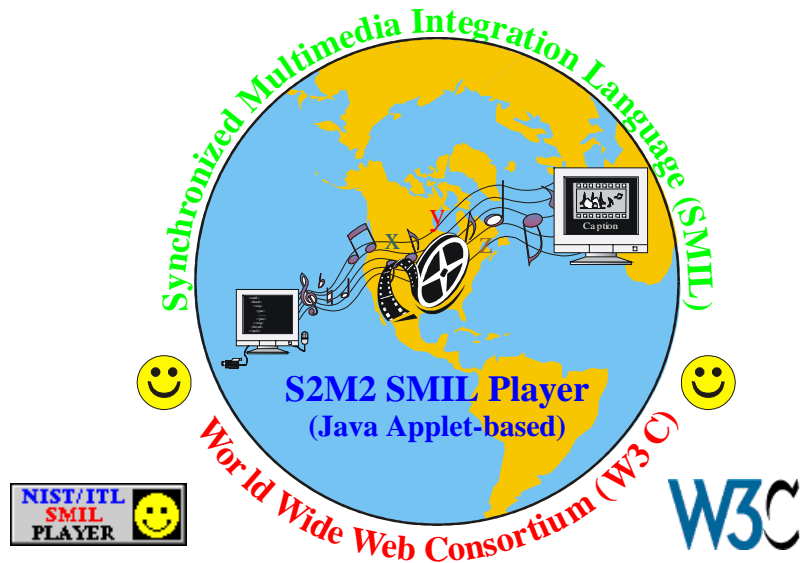
To develop new techniques and tools to test and evaluate the next generation Web multimedia presentation technology

To expedite standardization, commercialization and development of new Web multimedia content presentation technology

To deliver practical test and measurement technology to the multimedia research and product development industry

Collaborators / Customers

Standards Groups:
• W3C, IETF, MPEG

NIST Collaborators:
• MEL/NAMT

Industry Collaborators:
• Compaq with potential partners Lucent and Phillips

Customers:
• Companies, universities, consortium, federal labs.

Recent Products

W3C SMIL:
• Developed S2M2 Java Applet-based SMIL player (*open source soon*)
• Design & develop ACTS (Annotation Collaboration Tool via SMIL)
•Co-authored W3C's SMIL 1.0 Recommendation.

SMIL Interoperability Testing:
• Hosted First SMIL interoperability meeting at NIST
• Hosted vendors testing results at NIST (features listing, test suites)

Publications:
• *S2M2-Java Applet-based SMIL Player*, ICMTM Conference, Dec,1998
• *ACTS-Annotation Collaboration Tool via SMIL*, WWW8, May, 1999
•

SUMMARY OF STARTING WORK

IMT-2000 Evaluation
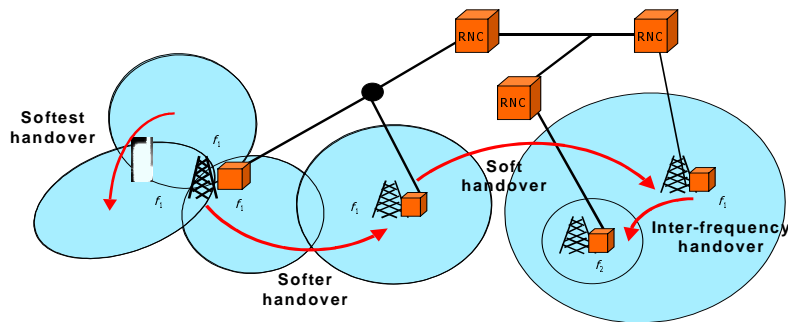
Objectives

To evaluate various technologies proposed for 3G wireless communication systems, and to contribute to the development of the IMT-2000 standard.

To develop cutting edge technologies to increase the capacity of future cellular communication systems.

To develop advanced techniques for transport of multimedia data in mobile communication systems.

Collaborators/Customers

- Industry Collaborators: **AT&T, Nokia, Nortel, Qualcomm**
- Federal Partners: **FCC, NTIA**
- Standards Groups**: TIA, ATIS T1, ITU**

Planned Products

Testbed for simulation and performance evaluation of third generation wireless technologies for different traffic patterns and over various channel conditions.

New algorithms and techniques to improve the performance of cellular wireless communication systems.

Technical contributions to standards for future mobile communication systems.

LMDS Performance Assessment

LMDS Band Allocation
(Local Multipoint Distribution Service)

28 & 31 GHz Band Plan
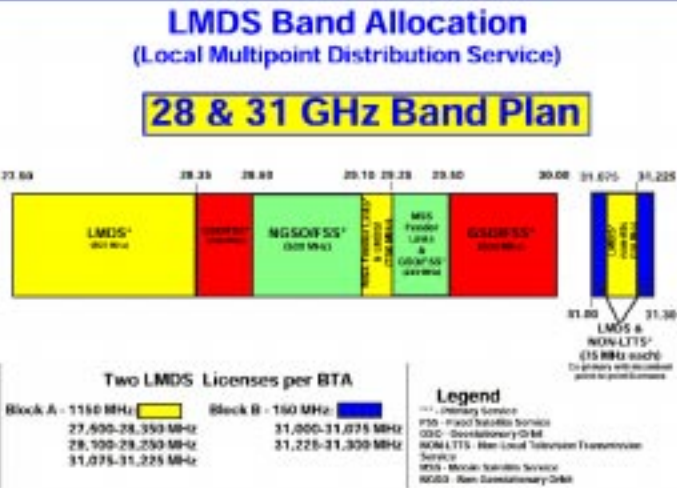
Objectives

To develop channel propagation models for the 30GHz frequency band incorporating nonlinearities in millimeter wave components and devices.

To develop adaptive equalization, coding, and modulation techniques for LMDS.

To contribute to the development of industry-consensus standards for LMDS.

Collaborators/Customers

• Industry Collaborators: **Lucent**
• NIST Collaborators: **EEEL, N-WEST, ATP**
• Federal Partners: **FCC**
• Standards Groups**: IEEE, ETSI**

Planned Products

Accurate channel propagation model for LMDS band taking into account weather-related attenuations and foliage.

Novel equalization, coding, and modulation techniques specifically developed for LMDS to ensure high quality video transmissions.

Contributions to yet nonexisting standards for LMDS.

Bluetooth Modeling & Assessment

Objectives

To evaluate the performance of Bluetooth in presence of other Bluetooth users and in face of ISM band interference from other devices.

To develop image/video transport mechanisms for Bluetooth.

To evaluate suitability of Bluetooth, and other wireless LAN technology for use in "Smart Spaces".

To verify and validate Bluetooth protocols, specifically the Link Manager Protocol (LMP).

Collaborators/Customers

- Industry Collaborators: **Ericsson, IBM**
- Federal Partners: **DARPA**
- Standards Groups: **Bluetooth SIG, WAP, Home RF**

Planned Products

A complete software reference implementation of a Bluetooth piconet taking into account interference from other piconets and ISM band devices.

Image/video transport algorithms specifically designed for Bluetooth environment.

Validation model for LMP.

Contributions to Bluetooth SIG in evaluating Bluetooth performance.

MANET Performance Assessment
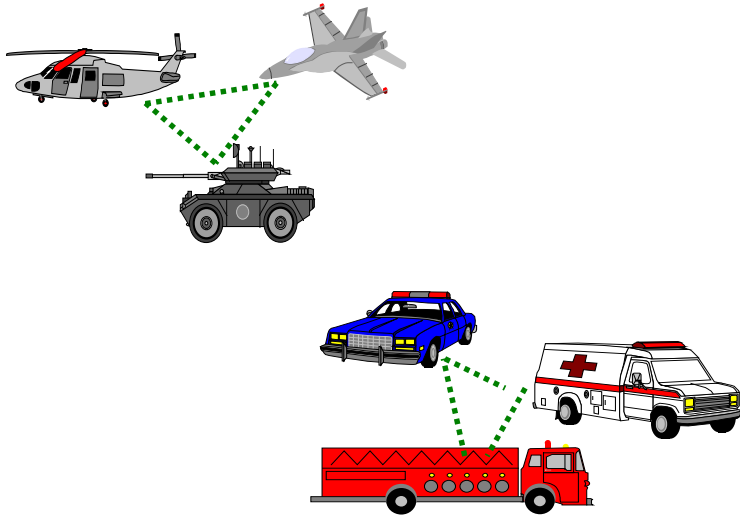
Objectives

To develop metrics and to measure the performance of various MANET protocols proposed to IETF and related protocols developed in DARPA GloMo Project.

To identify military and NS/EP critical features for MANETs and to encourage the adoption of these features in emerging MANET commercial standards.

To study the stability and scalability of MANETs.

Collaborators/Customers

• Industry Collaborators: **SAIC**
• NIST Collaborators: **ATP**
• Federal Partners: **DARPA, NCS**
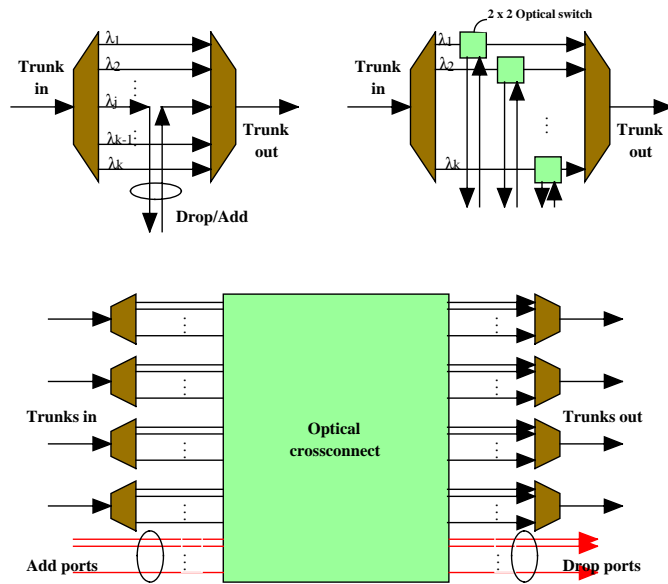• Standards Groups**: IETF**

Planned Products

Metrics for evaluating performance of MANET protocols.

An OPNET evaluation platform for MANET protocols.

Methods to ensure that MANET protocols remain stable as the network size grows.

Contributions to IETF standard for MANETs.

DWDM Network Metrology

Goal

To accelerate the development of multi-vendor interoperable metropolitan/local access DWDM (Dense Wavelength Division Multiplexing) networks.

Technical Objectives

- Develop methods to characterize very Dense WDM networks with narrow spacing (1GHz) at the optical level.
- Characterize the effect of optical signal parameters (e.g., s/n ratio, wavelength stability) on network behavior.
- Identify and demonstrate means of realizing reconfigurable/tunable multiplexers and routers and impact of network performance.
- Assess the performance of alternative proposals for service adaptation including IP over WDM.

Expected Impact

- Assist standards groups in development of standards and help industry to develop interoperable products.

Potential Customers and Collaborators

Customers
- Standard organizations: ANSI T1,ITU-T, Optical Internetworking Forum, IETF
- Bell Atlantic and other carriers
- Equipment vendors

Collaborators
- DARPA NGI/ONRAMP, MONET teams, Bellcore
- High Performance Systems and Services Division, ITL/NIST
- Physics Laboratory, NIST

Planned Accomplishments (FY 99-00)

- Establish a basic WDM testbed.   (FY 99)
- Install monitoring, test and measurement facilities. (FY 99)
- Publish results of study on optical signal parameters.(FY 99)
- Publish result of reconfiguration/protection studies. (FY 00)
- Develop facilities to study issues in transporting IP directly over WDM.   (FY 00)
- Conduct performance evaluation of IP over WDM. (FY 00)

WDM Network Planning and Modeling
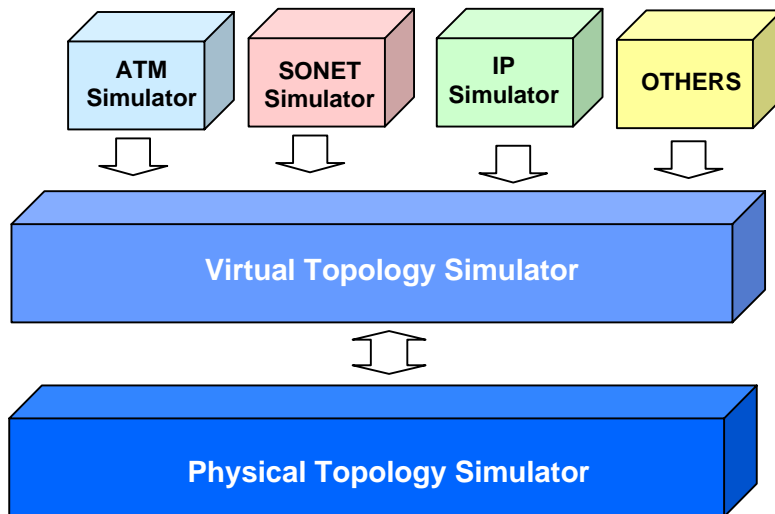
Goal

To speed the development of WDM technology for high speed networks.

Technical Objectives

- Develop software tools to simulate dynamic reconfiguration and physical layer characteristics of scalable WDM networks
- Develop and evaluate distributed algorithms for wavelength assignment and routing in WDM networks.
- Develop tool to analyze and design self-healing mechanisms in ring and mesh WDM topologies.

Expected Impact

- Use of the tool by participants in various standards organizations such as ITU-T, T1, and OIF to evaluate alternative proposals.
- Use by carriers to design WDM network topologies and to manage WDM networks.
- Use by researchers for protocol engineering and performance study.

Potential Customers and Collaborators

Customers
- Equipment vendors and network operators.
- Universities and research institutes.
- Standard organizations: ANSI T1,ITU-T, Optical Internetworking Forum, IETF.

Collaborators
- Optical simulation tool designers, vendors (BNeD, Bellcore)
- Physics Laboratory, NIST
- Mathematical Division, ITL, NIST
- Advanced Technology Program, NIST

Planned Accomplishments (FY 99 - 00)

- Develop a WDM network design and modeling environment which allows integration of existing analytical model and simulation software including ns2 and NIST ATM simulator.   (FY 99)
- Design and implement a library of efficient wavelength assignment and routing algorithms.   (FY 99-00)
- Design and implement a software tool for dynamic reconfiguration of WDM virtual topologies.   (FY 99-00)
- Integration of the above software into a tool for Modeling, Evaluation, and Research of Lightwave Networks, MERLiN.   (FY 99-00)

WORK UNDER CONSIDERATION

Internet Performance Measurement

1000-Byte Pings from minos.slac.stanford.edu to hephp1.ucsd.edu
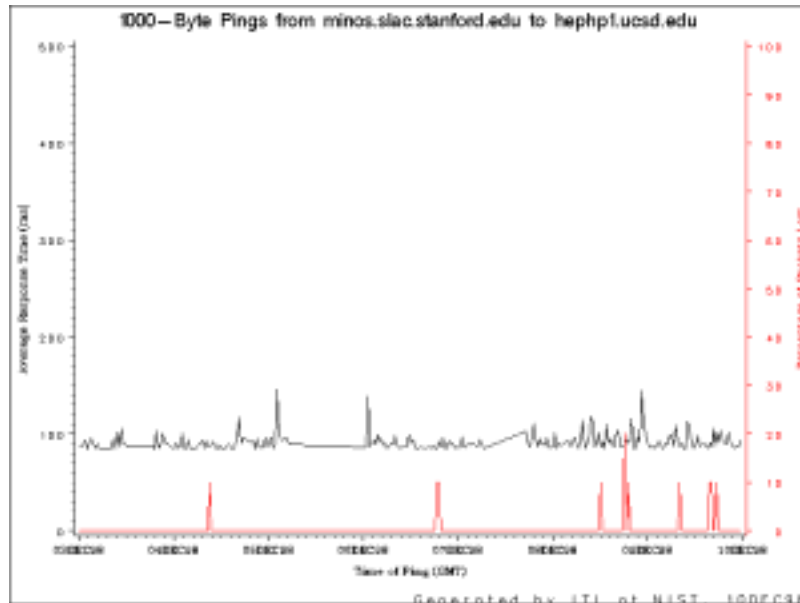
Goal

To advance the state of the art in Internet performance measurement through improved statistical analysis of the data that is collected and through improved data collection techniques.

Technical Objectives

- Improve measurement methodologies to support the industry demand for enforceable Internet Service Level Agreements (SLAs)
- Develop and deploy an Internet Performance Measurement toolkit.
- Develop passive measurement techniques.
- Improve data analysis.

Impact

- Reliable performance measurements permit consumers to evaluate the quality of the service they receive thus providing impetus for quality improvements.
- Passive measurement will reduce the perturbation caused by measuring the network performance.

Collaborators

Cross Industry Working Team (XIWT)
High Performance Systems Division
Statistics Division
Stanford Linear Accelerator (SLAC)
Advanced Network Systems (ANS)

Products and Results

- Established a test node and the data archive and analysis site for the XIWT/IPWT
  FY98

- Analyzed the "pinger" data and reported to the XIWT FY98

- Work performed to enhance the accuracy of the timestamp mechanism in the ANS Surveyor Probe device FY98
- GITS Internet Performance Measurement Toolkit developed   FY99
- GITS measurement systems deployed in the field FY00

WDM Network Quality of Service
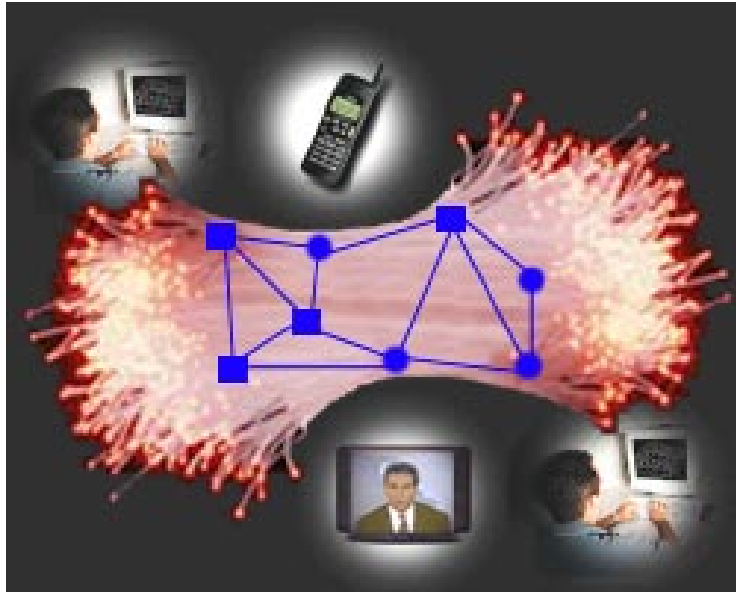
Goals

To achieve convergence between WDM QoS and QoS for exisiting network technologies.

Technical Objectives

- Define a QoS model for WDM networks including a set of parameters, service classes, protocols for QoS monitoring, parameter negotiation.
- Design QoS implementation schemes in WDM networks with respect to routing, wavelength assignment, reconfiguration and self-restoration.
- Propose and evaluate interworking mechanisms between existing QoS models (IP, ATM) and WDM QoS.

Expected Impact

- Achieve early consensus on the need for QoS and make it part of WDM reference architecture standards (OIF, ITU).
- Ensure that WDM protocols interwork with existing QoS in network technologies and provide support for multimedia.

Potential Customers and Collaborators

Customers
- Standard organizations: ANSI T1,ITU-T, Optical Internetworking Forum, IETF.
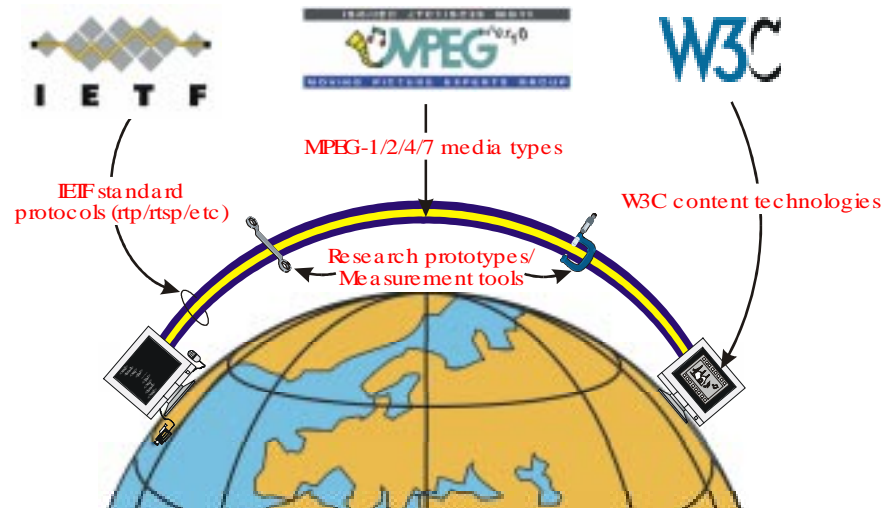- Universities and research institutes.

Collaborators
- DARPA, NGI program.
- Universities.

Planned Accomplishments (FY 99 - 00)

- Develop a WDM QoS principles and architecture.   (FY 99)

- Contribute our QoS principles and architecture model to the OIF/ANSI T1/ITU for inclusion in the architecture and requirement document.   (FY 99-00)

- Implement WDM QoS using MERLiN simulator.   (FY 00)

- Develop and evaluate algorithms for QoS wavelength assignment and routing.   (FY 00)

- Conduct a performance evaluation and devise optimization techniques for traffic driven reconfiguration.   (FY 00)

MPEG Testing and Evaluation

MPEG-1/2/4/7 media types

IETF standard protocols (rtp/rtsp/etc)

W3C content technologies

Research prototypes/ Measurement tools

Objectives

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To develop new techniques and tools to test and evaluate the next generation of object-based multimedia presentation technology

To expedite standardization, commercialization and development of new object-based content presentation technology

To deliver practical test and measurement technology to the multimedia research and product development industry

Collaborators / Customers

Standards Groups: MPEG, SMPTE

NIST Collaborators: ATP

Other Collaborators: Academic and industry researchers (UMd, GWU, University of Oulou, Finland, and NOKIA), developers of reference implementations in France, Israel, and Italy.

Customers: Tektronix, French Telecom USA, NIH, UMd.

Planned Accomplishments

MPEG Standards:
• Establishing 2D/3D BIFS testing profiles
• Contributions to MPEG-4 conformance
• Software tool to study the effects of splicing
Metrics to evaluate image quality
•Extend the present modeling techniques; test existing and new techniques against a larger corpus of images.
Image and video Indexing:
•Investigate new indexing techniques, develop software to implement them, test such techniques against the state of the art.